A Wide-Area Surveillance Prototype System from Identification Fusion Perspective

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Along with our efforts to prepare an operational prototype for a wide area surveillance system, identity fusion was considered as one of the major system components. Many problems have been detected about how the sensors produce the identity information, how they sent this information, registration of the information, detecting the conflicts, combining the appropriate information in an effective way, the presentation of the final fused information to the operators, and consequently interpreting the results for the coordination of sensors for further identification efforts. On the other hand, the appropriate way of integrating identity information to the rest of the fusion process constitutes the other important context. In this paper, we report our experience for a wide area surveillance system from identification fusion perspective based on the prototype system developed in Turkish Navy Research Center Command.

1.0 INTRODUCTION

Different type of threats, changing hostile activities, dense operational areas, littoral waters, and asymmetric threat expectations increase the significance of the classification and identification process in a maritime surveillance system. Although many different types of evolving sensors are utilized in modern surveillance systems, it is still a challenging task to establish and maintain the “recognized tactical picture”.

As the threats and threat evaluations have been changing, associated identification process has become more complex in military surveillance systems. Littoral Warfare and operations other than war concepts has created different and more challenging requirements in both the content and timing requirements of the identification information of the tactical picture.

As the requirements are getting more challenging, the surveillance systems are getting better especially by adapting their sensors to a “network centric”, “network oriented” or “network enabled” systems. But unfortunately, despite very nice definitions and explanations, we observe that there are still some very important technical challenges to achieve in network centric applications.

Different multi sensor data fusion techniques are utilized in establishing the recognized maritime tactical picture. In most general sense, the first level of multi-sensor data fusion, known as parametric fusion is considered in two main stages: Positional fusion and identity fusion. On the other hand, the interactions of the second and third level fusion, namely situation assessment and threat evaluation is not always a clear cut especially when the identification fusion is considered.

In this paper, we cover some of the problems that we faced in a prototype maritime surveillance system from identification fusion perspective. To cover the material in an organized way, we group the problems

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as technical and operational problems; where as technical problems can further be grouped as architectural and fusion process aspects.

We introduce the problem in more detail with a brief explanation of our prototype system in section 2. In section 3 we cover the technical problems covering both architecture and fusion process aspects. Section 4 deals with operational problems. Section 5 concludes our report.

2.0 PROBLEM DEFINITION

A wide-area surveillance system is a good example of multi-sensor, multi-site fusion system with potentially many different type and number of systems, located in different geographical locations and covering many different types of “targets”.

Such a surveillance system has been prototyped in Turkish Navy Research Center Command to try out various techniques in actual system development. Main components of the prototype system are:

- Distributed sensor simulation system
- Fusion node prototype
  - Sensor Integration Units
  - Fusion and Command Tactical System (FACTS)
- Communication media simulation system

In the distributed sensor simulation environment you can create off-line scenarios. These scenarios can be modified during the run-time as they provide the ground-truth information for the sensor simulators. When these scenarios are run, sensor simulators receives the ground-truth information, evaluate their coverage, and creates sensor tracks with a medium fidelity, which we consider as satisfactory for our prototype purposes.

After the appropriate track management, the sensors report their track information to the fusion center, via very realistic communication media simulation system, which is in our case a land-based communication system.

In the prototype fusion node, where all of the information is collected and processed, FACTS, has the main processing functionalities. It has mainly two different modules:

- Multi-sensor data fusion module (MSDF), and
- Tactical level fusion module (TM)

where MSDF module performs actual fusion process and TM provides services for operator input and presentations for higher levels evaluations and interactions.

At this point we need to emphasize the differences between the organic and non-organic sensors in such a fusion system. Sensors which are controlled, operated and monitored directly within the fusion system are considered as organic sensors, where as sensors or systems which provide information to the fusion system indirectly, mostly after an evaluation process are considered as non-organic sensors.

Within this context, MSDF has been designed and implemented in order to fuse data and information from different number and types of organic sources. Modern fusion algorithms and techniques can be studied within this module. On the other side, TM is designed to integrate non-organic data and operator evaluations into the system.

In a wide-area maritime surveillance system that can be simulated effectively with the above described prototype system, we faced many problems starting from very basic concepts regarding the simulation process up to the distribution of the recognized maritime tactical picture established. We choose evolutionary prototyping method. It was useful since it has provided a common environment to exchange ideas and evaluate the results before the system gets unmanageable. Another important system wide problem was to decide about the alternative algorithms to be implemented in the prototype system. Different risk evaluations, concerning performance, infrastructure, integration, and available resources has led sometimes the selection of not the best algorithm evaluated.

Two main important modules of parametric fusion, positional and identity fusion are designed and implemented in an integrated but modular manner. Although there are some recent efforts in the literature to integrate the identity information in the early stages of the positional fusion, even in the association phase, to get better association results, we have utilized the methods which integrate the identity information in later stages of the fusion process, especially after the positional fusion process.

In order to explain the problems from identification process, which we concentrate in this paper, we divide these problems in two different groups as technical and operational. Technical problems are further detailed as architectural and identification fusion process related.

3.0 TECHNICAL PROBLEMS

There are some technical challenges to be taken into account in any large-scale fusion system. These problems, which we named as architectural problems are listed below for the sake of completeness and detailed in [2]. These architectural problems are:

- Different types of sensors,
- Different types of systems, subsystems,
- Different types of communication media and communication requirements,
- Different types of information processing techniques,
- Effective presentation to the operators and to the command team, (Human Machine Interface),
- Effective sensor and resource management.

On the other hand, there are some problems that we faced related to identification process specifically. These problems are defined in [3] to some extend. We enhance these explanations based on our experience in the rest of this section.

First of all, due to its significance we emphasize that sensor related issues constitutes a great problem by itself, due to:

- Different types of sensors reporting different types of identification information,
- Unknown characteristics of the sensors,
- Uncertainties associated with their reports,
- Difficulties to enforce the sensor manufacturers to think appropriately for fusion purposes.

Most of the sensors are generally designed in more of a stand-alone system. As the integrated systems, systems of systems and finally network-centric warfare concepts evolves, it becomes inevitable to require some changes in the specification of the sensors. Acknowledging the increasing significant role of the “system engineers” role in large-scale projects, system engineers have to consider many different topics, which will definitely include the very detailed capabilities of each sensor providing some kind of data to the fusion process. In many cases, knowing only the capabilities of the sensors will not be enough, but the algorithms and even some implementation details of the sensors will be necessary for the success of the overall system performance.

As the basic step of the parametric fusion process, association (or in some literature correlation) serves both for the positional and identification fusion purposes. A successful association mechanism is the key element for a successful identification process. Assuming that association has been done successfully, we can enhance identification fusion problems as follows:

- Processing combat id (hostile, friend, suspect, etc) and identification information (type A, Class B, platform X) separately is a major design decision in the system. It is partially due to the fact that the significance of these two different levels of classification has different operational requirements. In any case, the first goal is to provide a combat id to the operator. Combat id is more fundamental and it has some well-known regulations and rules defined in operational documents. On the other hand, identification information provides more information about a specific target. Although there is a close relationship between combat id and identification information, these two can be processed independently up to a certain decision level. Identification information after having some conflict checks with the combat id, will be used for situation assessment and threat evaluation purposes.
- Concentrating on the identification information and its fusion process, we need to consider different identification information produced by the sensors. For most of the sensors, it is not very well defined how they produce the identification information associated with a specific track. Hence very careful study of the sensor data is required. Most of the time, understanding of the internal sensor processing is vital for a successful fusion process.
- When these data or information is sent to Fusion center or fusion node, appropriate registration mechanisms are to be done effectively. This covers converting possibly different types of information, such as possibility, probabilistic, linguistic and likelihood values to a common information domain.
- Detecting the possible conflicting information reported by the same sensor and resolving these conflicts, either automatically or via interactions with the operator constitutes the next step in the fusion process. Conflicting reports from a specific sensor may affect the result of the identification fusion process significantly, hence we think that before making such reports effective on the fusion process, potential conflicts have to be checked and resolved. Actually it is a way of having a safety-point in the identification fusion process, since we are not sure about the quality of the identification data/information sent by the sensors automatically. In order to be able to keep the system reliable for the end user, we think that it is worthwhile to put some more effort (computer and operator if needed) to check for the inconsistent reports.
- Similar conflict checks are also to be performed within the reports of different sensors for a specific target. Detecting the possible conflicting information reported by different sensors and resolving these conflicts is necessary for maintaining reliable results.
- After these conflict checks identification information combining process takes place. Bayesian and Dempster-Shafer models form two main approaches for combining the identification information. We have also got some experience with the Transferable Belief Model (TBM) [4], which is actually an interpretation of Dempster-Shafer model. Although we have not a clear-cut idea on which algorithm to utilize for the final system, TBM gives promising results for scenarios with specific problems.
- The presentation of the combined information to the operator in an understandable format is still an important issue. The operator needs to have access to the information sent by the sensors, the identification information calculated by the system (if necessary after a pruning process) and

some resultant identification information that is either generated by the system or operator. Operator needs to be able to modify the resultant identification information even if it is generated by the system automatically.

- On the other hand the content of the identification information presented to the operator is also important. Especially in DS and TBM methods, basic probability assignments (mass values), Belief and Plausibility values calculated after the combining process, are difficult to be visualized by the operators, especially by the end users. Hence either a very detailed training shall be given to the operators, or automatic conversions have to be implemented for more custom values such as probability values. A conversion method is proposed in [4] by Delmotte and Smets.
- An additional consistency check is very useful between the resultant identification information and the other data gathered from different sources such as intelligent reports, operational messages and even information via a Geographical Information system.
- In almost every step there is a conflicting check requirement. This is mostly due to the requirement to maintain the high level of reliability through out the system. In most cases, having no result is considered as better than producing a wrong result. Hence we prefer to process the data automatically as much as we can, but if there is a doubt the task is to alert the operator about the problematic case.
- The effect of the identification information fusion on the positional fusion results, especially on the association process has also to be taken care of by the system. Especially a conflict report is approved by the operator for a track reported by more than one sensor then operator shall be provided with the tools/services to maintain the association relation appropriately.
- As it can be followed all the issues that we mentioned are strongly related to the organic sensor information process. There are also some additional problems in the Tactical Level Fusion process from the technical challenges of the identification fusion perspective:
  - The management of identification information retrieved from more than one link shall be handled appropriately.
  - For the conflict resolution between different links and organic sensors, we utilize operator support. But automation of identification information assignment can be performed to a certain extend without any operator interaction.

4.0 OPERATIONAL PROBLEMS

While there are some technical challenges in the identification fusion process, operational requirements constitute the other important aspect of the identification fusion process. Our explanation will start from the sensors, continue with the communication media and conclude with the fusion node itself.

The independent sensors and their operators must have a clear idea about the general overall fusion concept. They may even be warned against the results of their ignorance in their scope. On the other hand, this may also affect the track exchange policies of the fleet, which may cause some extra difficulties to maintain the existing link communication. Nevertheless, the important thing is that a track that is not important for one sensor may be vital for another unit. Hence we need to exchange the track information to the extend possible without any filtering if possible. Since this will most likely cause a bottleneck in the communication media, alternative communication possibilities or operational procedures shall be utilized.

The significance of the communication capabilities can be seen very easily in such an integrated surveillance system. Most of the time, alternative communication mechanisms are to be established both to collect data and to distribute the resultant tactical picture effectively.

Secure voice capabilities between appropriate commanders and secure coordination networks for specific purposes, such as EW or AAW is of special interest. Again due to the limitation of the available communication channels, some of the coordination may be supported via text messaging between the operators or even between the commanders.

As we mentioned briefly, assigning an appropriate combat id for a track is more important than producing an identification information for that specific track. But in any case, they need to be complementary. Any conflicting case is a potential issue to investigate for the tactical picture compilers. This process can easily be automated to save time and man power.

Commander/ Decision makers shall not be expected to know all the details of the surveillance and identification fusion process, but instead there shall be some other people who will be in charge of coordination of the surveillance process and the evaluation of the intermediate results. In most cases, it is a good idea to have one or more identification officer to support the commander for these tasks.

Identification officer should have detailed information about the capabilities, limitations, and even the underlying algorithms of the integrated sensors and communication systems of the overall surveillance system.

Operational organization of the fusion node or in more general sense fusion center is very important to achieve the targeted goal. Although the organization is to be flexible with respect to the given scenario, the workflow of the fusion center is very important for the successful result. Within this context, the presentation of the tactical picture internally, the filtering mechanisms, switching between different operator console screens, the video-wall applications, internal communication capabilities are all to be considered as parts of workflow of the fusion center.

It is our experience that to enable some operators to access the detailed information gives a good confidence over the system. Hence the related operators, including the identification operator, shall have access to the sensor reports, their details and possibly the history of the sensor reports; the calculated identification information produced by the sensor, the pruned version of the calculated identification information if necessary and the resultant identification information.

In order to establish and maintain the recognized tactical picture appropriately, the coordination of the sensors and available resources shall also be considered as an important operational aspect. Especially the allocation of extra resources to identify a specific track requires a comparison of potential threat and necessary resource allocation. We think that there will be some automated tools to support the decision makers for this specific resource allocation problem.

The presentation of the compiled picture to the operator and command team is still another problematic issue. There are no generally accepted standards to present the tactical picture so that operators and command team can evaluate the current situation effectively. On the other side, in terms of human machine interface (HMI) presentation is not the only issue. Our concern is that the reliability and confidence of the overall system as observed and evaluated by its operators and users is much more important and vital. We have observed many systems not being used effectively just because of the missing feelings of the confidence. Hence, great care shall be given, not to disturb the confidence of the operator to the system, as a continuous process starting from analysis of the system up to and including maintenance phase of the system.

5.0 RESULTS

Our experience in the prototype system showed that sensors, their characteristics, and (sometimes) unreleased parts have significant effect in selecting, designing and implementing the appropriate fusion system. As there is no well-defined procedure for identification fusion process, we benefit our modular architecture so that we can plug and test any kind of identification fusion algorithms in our system or we can enhance our existing implementation. One of our conclusions is that belief theory deserves more attention in the identification fusion implementations with its superior characteristics fitting our purposes.

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